SECTION 502
TEMPORARY STRUCTURES

502.01. DESCRIPTION.

This work consists of designing, constructing, and removing temporary structures used in the construction of highway bridge structures. Temporary structures include falsework, formwork, temporary retaining structures, temporary water control systems, and detour bridges.

Falsework is any temporary construction used to support the permanent structure until it becomes self-supporting. Formwork is the temporary structure or mold used to retain plastic or fluid concrete in its designated shape until it hardens. A temporary retaining structure is used to temporarily hold the surrounding earth and water out of an excavation and to protect adjacent property and facilities during construction of the permanent work. A temporary water control system is used to divert surface water or ground water to prevent such water from entering an excavation. A detour bridge conveys public or construction traffic during construction of the permanent work.

502.02. MATERIALS.

(a) **Falsework.**

1. *General.* Use materials, new or used, manufactured components, or a combination of these materials in falsework construction. Use concrete, reinforcing steel, and structural steel conforming to the following Sections.

Structural Steel	506
Structural Concrete (*Class A*)	509
Reinforcing Steel for Structures	511

Supply material certifications for new materials, if directed. Perform concrete tests described in Subsection 701. All salvaged and used material and manufactured components are subject to approval.

2. *Salvaged Steel.* Used structural steel satisfying ASTM A6 criteria for surface imperfections may be used in falsework construction at the allowable working stresses for new material if the grade of steel can be identified. If the steel cannot be identified, use the allowable stresses specified in this Section.

3. *Timber.* All wood species assigned allowable stresses in the *National Design Specification for Wood Construction* (NDS) Supplement, 1991 edition, as published by the National Forest Products Association are acceptable for use in falsework construction.

4. *Used lumber.* Used lumber of known species may be used in falsework construction under the following conditions:

   - If the grade is known and the lumber is in good condition, use the allowable stresses not exceeding those for new lumber of the same grade.
   - If the grade is unknown, use the lowest NDS allowable stresses for the species with appropriate reductions for condition.

5. *Manufactured components.* Manufactured components of the following proprietary product classes may be used:
   - Vertical shoring systems including tubular welded frame shoring, tube and coupler shoring, and components thereof.
   - Manufactured assemblies including single-post shores, brackets, jacks, joists, clamps, and similar devices manufactured for commercial use.

(b) **Forms.**

1. *General.* Use concrete forms that are mortar-tight, true to the dimensions, lines, and grades of the structure, and of sufficient strength to prevent appreciable deflection during concrete placement.
2. *Sheathing.* For exposed concrete surfaces, use U.S. Product Standard PS 1 for Exterior B-B (Concrete Form) Class I Plywood or other approved material that will produce a smooth and uniform concrete surface. Use only form panels in good condition free of defects on exposed surfaces. If form panel material other than plywood is used, it shall have flexural strength, modulus of elasticity, and other physical properties equal to or greater than the physical properties for the type of plywood specified.
3. *Structural Support.* Use materials for structural support of forms complying with the materials requirements for falsework. Vertical side forms, wall forms and column forms and related studs, walers, etc. are considered formwork or structural support for formwork.
4. *Prefabricated Formwork.* If prefabricated formwork is to be used, furnish shop drawings under Subsection 105.02 and technical data substantiating load-carrying capacity and detailing application instructions and limitations of use. Use prefabricated products according to manufacturer's recommendations.
5. *Stay-in-Place Steel Deck Forms.* Stay-in-place steel deck forms may be used only when permitted in the contract documents or approved by the Engineer.

   If used, meet the requirements for prefabricated formwork. Furnish design calculations with shop drawings. Fabricate stay-in-place steel deck forms and supports from steel conforming to ASTM A 653, Grades 40(275) and 50(340), having a coating class of G165 according to ASTM A 525.
6. *Stay-in-Place Prestressed Concrete Deck Forms.* Stay-in-place prestressed concrete deck forms may be used only when permitted in the contract documents or approved by the Engineer.

   If used, meet the requirements for prefabricated formwork. Furnish complete deck design calculations with the shop drawings. Fabricate stay-in-place deck forms according to Section 503.

502.04. CONSTRUCTION METHODS.

(a) **Falsework.** Employ a professional engineer registered in Oklahoma to design falsework if the falsework is to be more than 14 feet (4.3 m) tall, or traffic, other than workmen involved in constructing the bridge, will travel under the falsework.

1. *Working Drawings.* Prepare and submit drawings of the required falsework design according to Subsection 105.02. Include the following, as applicable:

- *General.* Design and show the details for constructing falsework that provides the necessary rigidity, supports the loads imposed, and produces the required lines and grades in the finished structure. Use a registered professional engineer proficient in structural design to design, sign, and seal the drawings. The design calculations shall show the stresses and deflections in load supporting members.
- *Submission Sets.* Submit three sets of falsework drawings and one set of design calculations for approval.
- *Design Details.* Include the information and details necessary to enable falsework construction without reference to any supplemental drawing, calculation sheet, design standard, or other source document. Show all design-controlling dimensions, including beam length, beam spacing, post location and spacing, vertical distance between connections in diagonal bracing, height of falsework bents, and similar dimensions controlling falsework design and erection.
- *Foundation Loads.* Show the maximum applied structural load on the foundation material. Include a drainage plan or description of how foundations will be protected from saturation, erosion, and/or scour.
- *Materials Specifications.* Precisely describe all proposed falsework material. Describe the material that is not describable by standard nomenclature (such as AASHTO or ASTM specifications) based on manufacturer's tests and recommended working loads. Evaluate falsework material and ascertain whether the physical properties and conditions of the material are such that it can support the loads assumed in the design.
- *Concrete Placement.* Provide an outline of the proposed concrete placement operation listing the equipment, labor, and procedures to be used for the duration of each operation. Include proposed placement rates and design pressures for each pour. Include a superstructure placing diagram showing the concrete placing sequence and construction joint locations.
- *Settlements.* Show anticipated total settlements of falsework and forms. Include falsework footing settlement and joint take-up. Design for anticipated settlements not to exceed 1 inch (25mm). Design and construct the falsework to elevations that include anticipated settlement during concrete placement and required camber to compensate for member deflections during construction.
- *Traffic.* Where openings through the falsework are required to permit the passage of public traffic, show the location of all such openings, including horizontal and vertical clearances and the location of temporary railing. For falsework over traffic, show the sequence of falsework erection and removal.

  Submit separate falsework drawings for each structure, except for identical structures with identical falsework design and details. Do not start construction of any unit of falsework until the drawings for that unit are reviewed and approved.

2. *Design Limitations.* The allowable maximum design stresses and loads listed in this section are based on the use of undamaged, high-quality material. If lesser quality material is used, reduce the allowable stresses and loads.

Limit the vertical deflection of falsework members to 1/500 of their span under the dead load of concrete. When computing deflection, neglect the deflection-reducing effect of camber strips and use 1700 ksi (11.7GPa) and 30,000 ksi (210GPa) for the modulus of elasticity (E) of wood and steel, respectively.

Do not exceed the following maximum stresses, loads, and deflections in the falsework design:

2.1 *Timber.* For designing timber members, comply with allowable stresses, for the wood species to be used, as assigned by the *National Design Specification for Wood Construction* or the following.

- Compression, perpendicular to the grain = 450 psi. (3.1 MPa)
- Compression, parallel to the grain = $\frac{480{,}000}{(L/d)^2}$ psi $\left(\frac{3309}{(L/d)^2}(\text{ MPa})\right)$

  or 1600 psi (11 MPa) maximum,

  where: L = the unsupported length,

  d = the least dimension of a square or rectangular column or the width of a square of equivalent cross-sectional area for round columns.
- Flexural stress = 1800 psi (12.4MPa) (reduce to 1450 psi (10.0 MPa)for members with a depth of 8 inches (200 mm) or less.)
- Horizontal shear = 190 psi (1.3MPa).
- Axial tension = 1200 psi (8.3MPa).
- Axial loading on timber piles = 45 tons (400KN).

Design timber connections according to the stresses and loads allowed in the *National Design Specification for Wood Construction*, except:

- Reductions in allowable loads required therein for high moisture condition of the lumber and service conditions do not apply.
- Use 75% of the tabulated design value as the design value of bolts in two member connections (single shear).

2.2 *Steel.* For identified grades of steel, do not exceed the allowable design stresses specified in the AISC Manual of Steel Construction except as noted. For all grades of steel, do not exceed the following design stresses:

- Compression, flexural = $\frac{12{,}000}{Ld/bt}$ ksi $\left(\frac{82{,}750}{(Ld/bt)}(\text{MPa})\right)$

Note: Do not exceed 21.6 ksi (150 MPa) for unidentified steel or steel conforming to ASTM A 36. Do not exceed 0.6 F_y for other identified steel.

where: L = the unsupported length,

d = the least dimension of a square or rectangular column or the width of a square of equivalent cross-sectional area for round columns or the depth of beams,

b = the width of the compression flange,
t = the thickness of the compression flange,
r = the radius of gyration of the member,
F_y = the specified minimum yield stress for the grade of steel used.

When the grade of steel cannot be positively identified, do not exceed the allowable design stresses either specified in the AISC Manual for ASTM A 36 steel or the following:

- Tension, axial and flexural = 21.6 ksi (150 MPa)
- Compression, axial = 16 - 0.00038$(L/r)^2$ ksi (110-0.00262$(4r)^2$MPa), except L/r shall not exceed 120.
- Shear on the web gross section of rolled shapes = 14.4 ksi (100 MPa)
- Web crippling for rolled shapes = 27.0 ksi (190 MPa)

2.3 *Other requirements.* Limit falsework spans supporting cast-in-place reinforced concrete T-beam girder bridges or slab-span bridges to 13 feet (4m) plus 8.5 times the overall depth of T-beam girder or minimum depth of the slab-span, respectively. This requirement does not apply to either pan girder bridges or prestressed double tee bridges.

2.4 *Manufactured assemblies.* For jacks, brackets, columns, joists and other manufactured devices, do not exceed the manufacturer's recommendations or 40% of the ultimate load carrying capacity of the assembly based on the manufacturer's tests or additional tests ordered. Limit the maximum allowable dead load deflection of joists to 1/500 of their spans.

Furnish catalog or equivalent data showing the manufacturer's recommendations or perform tests, as necessary, to demonstrate the adequacy of any manufactured device proposed for use. Do not substitute other manufacturer's components unless the manufacturer's data encompasses such substitutions or field tests reaffirm the integrity of the system.

If a component of the falsework system consists of a steel frame tower exceeding two or more tiers high, the differential leg loading within the steel tower unit shall not exceed 4 to 1. An exception may be approved if the manufacturer of the steel frame certifies, based on manufacturer's tests, that the proposed differential loadings are not detrimental to the safe load carrying capacity of the steel frame.

3. *Design Loads.* Design falsework for the specified combinations of vertical loads and horizontal loads.

3.1 *Vertical Loads.* Vertical loads consist of the following:

- *Dead Load.* Dead loads include the weight of concrete, reinforcing steel, forms, and falsework. Assume the density of concrete, reinforcing steel, and forms to be not less than 160 lb/ft^3 (2600 kg/m^3) for normal concrete and not less than 130 lb/ft^3 (2100 kg/m^3) for lightweight concrete. Consider the entire superstructure, or any concrete weight being supported by falsework to be a fluid dead load with no ability to support itself.

- *Live Load.* Consider live loads to be the actual weight of equipment to be supported by falsework applied as concentrated loads at the point of contact plus a uniform load of not less than 20 lb/ft^2 applied over the area supported, plus 75 lb/ft (1100 N/m) applied at the outside edge of deck falsework overhangs.
- *Redistributed Prestress Load.* If the concrete is to be prestressed, design the falsework to support any increased or readjusted loads caused by the prestressing forces.
- *Impact.* When impact can occur, increase by at least 30% the design load causing the impact on steel members and manufactured components.
- *Minimum Vertical Load.* Use a minimum total vertical design load of not less than 100 lb/ft^2 (4800 Pa). The total vertical design load for falsework is the sum of dead and live vertical loads.

3.2 *Horizontal Loads.* Horizontal design loads consist of the sum of the actual horizontal loads due to equipment, construction sequence, or other causes and an allowance for wind and stream flow.

Use an assumed horizontal design load on falsework towers, bents, frames, and other falsework structures to verify lateral stability. Design the falsework so the falsework has sufficient rigidity to resist the assumed horizontal load without vertical dead load. Neglect the effects of frictional resistance. Use an additional safety factor against overturning of at least 1.2.

- *Wind Load.* The minimum wind allowance for each heavy-duty steel shoring having a vertical load carrying capacity exceeding 30 kips (130 kn) per leg is the sum of the products of the wind impact area, shape factor, and the applicable wind pressure value for each height zone. The wind impact area is the total projected area of all the elements in the tower face normal to the applied wind. Assume the shape factor for heavy-duty shoring to be 2.2. Determine wind pressure values from Table 502-1.

Table 502-1
Design Wind Pressure - Heavy Duty Steel Shoring

Height Zone Above Ground ft (m)	Wind Pressure Value, psf (Pa)	
	Adjacent to Traffic	At Other Locations
0 - 30 (0-9)	20 (960)	15 (720)
30 - 50 (9-15)	25 (1200)	20 (960)
50 - 100 (15-30)	30 (1450)	25 (1200)
Over 100 (over 30)	35 (1675)	30 (1450)

The minimum wind allowance on all other types of falsework, including falsework supported on heavy-duty shoring, is the sum of the products of the wind impact area and the applicable

wind pressure value for each height zone. The wind impact area is the gross projected area of the falsework and unrestrained portion of the permanent structure, excluding the areas between falsework posts or towers where diagonal bracing is not used. Use design wind pressures from Table 502-2.

Table 502-2
Design Wind Pressure - Other Types of Falsework

	Wind Pressure Value, psf (Pa)	
Height Zone Above Ground ft (m)	For Members Over and Bents Adjacent to Traffic Openings	At Other Locations
0 - 30 (0-9)	2.0 Q (320 Qm)	1.5 Q (240 Qm)
30 - 50 (9-15)	2.5 Q (400 Qm)	2.0 Q (320 Qm)
50 - 100 (15-30)	3.0 Q (480 Qm)	2.5 Q (400 Qm)
Over 100 (over 30)	3.5 Q (560 Qm)	3.0 Q (480 Qm)

NOTE Determine the value of Q, if applicable, in the above tabulation as follows: Q = 1 + 0.2W (Qm=0.3+0.2W), but not more than 10 (3). W is the width of the falsework system in feet (meters) measured in the direction of the wind force being considered.

- *Stream Flow.* When falsework supports are placed in flowing water, determine water pressure by the following formula:

  $$P_w = C_D V^2 \quad (P_w = 514 C_D V^2)$$

  where P_w is the pressure of flowing water in lb/ft^2(Pa), V is the water velocity in feet/sec (m/s), and C_D is the drag coefficient having the following values:

  0.7 for a semicircular nosed pier,

  1.4 for a square ended pier,

  1.4 for debris lodged against a pier,

  0.8 for a wedged nosed pier with nose angle 90° or less.

  Investigate scour depths as necessary.

- *Lateral fluid pressure.* For concrete with retarding admixture, fly ash, or other pozzolan replacement for cement, design forms, form ties, and bracing for a lateral fluid pressure based on concrete with a density of 150 lb/ft^3 (2400 kg/m^3). For concrete containing no pozzolans or admixtures, which affect the time to initial set, determine the lateral fluid pressure based on concrete temperature and rate of placement according to ACI Standard 347R, *"Guide for Formwork for Concrete."*
- *Minimum Horizontal Load.* Use a minimum horizontal load of at least 2% of the total supported dead load at the location under consideration.

4. *Load Combinations.* Design falsework for the load combinations shown in Table 502-3.

Table 502-3
Load Combination

Load Combination	Percentage of Basic Allowable Stress or Load
DL+DP+LL+I+H	100%
DL+DP+PS+H	100%
DL+DP+LL+I+W+SF	133%
DL+DP+LL+PS+W+SF	133%

where: DL = design dead load,
DP = dead load of supported permanent structure,
LL = construction live load,
I = impact load,
H = minimum horizontal design load,
PS = redistributed prestress load,
W = wind load,
SF = stream flow load.

5. *Slenderness.* For compression members, limit the slenderness ratio, Kl/r, to the following:
   - Main load-carrying members:
     180 for steel,
     100 for aluminum.
   - Bracing members:
     200 for steel,
     150 for aluminum.

   Limit the slenderness ratio of tension members other than guy lines, cables, and rods, to a maximum of 240 for main members and 300 for bracing members.

6. *Falsework Foundations.* Field verify all ground elevations at proposed foundation locations before design.

   Where spread footing type foundations are used, determine the bearing capacity of the soil. The maximum allowable bearing capacity for foundation material, other than rock, is 2 tons/ft^2 (200 kPa).

   Do not locate the edge of footings closer than 12 inches (300 mm) from the intersection of the bench and the top of the slope. Unless the excavation for footings is adequately supported by shoring, do not locate the edge of the footings closer than 4 feet (1.2m) or the depth of excavation, whichever is greater, from the edge of the excavation.

   When a pile type foundation is used, construct according to Section 514. When falsework is supported by footings placed on paved, well-compacted slopes of berm fills, do not strut the falsework to columns unless the column is founded on rock or supported by piling.

Size spread footings to support the footing design load at the assumed bearing capacity of the soil without exceeding anticipated settlements. Provide steel reinforcement in concrete footings.

When individual steel towers have maximum leg loads exceeding 30 kips (130kN), provide for uniform settlement under all legs or each tower under all loading conditions.

Protect the foundation from adverse effects for the duration of its use. Advise the Engineer of actions that will be taken to protect the foundation.

7. *Proprietary shoring systems.* If proprietary shoring systems are to be used, furnish a letter of certification from the shoring manufacturer stating that the shoring system is being used in accordance with the manufacturer's recommendations for loads and conditions of use.

8. *Falsework Over or Adjacent to Roadways and Railroads.* Design and construct the falsework to be protected from vehicle impact. Provide protection for:

   - falsework supports for members crossing over a roadway or railroad,
   - other falsework supports if the horizontal distance from the traffic side of the falsework to either the edge of pavement or a point 10 feet (3m) from the centerline of track is less than the total height of the falsework.

   Provide additional features to ensure that this falsework will remain stable if subjected to impact by vehicles. Increase vertical design loads by 150% for these falsework supports, including posts, columns, and towers, but not footings.

   Install temporary concrete traffic barriers before erecting falsework towers or columns adjacent to an open public roadway. Locate barriers so that falsework footings or pile caps are at least 3 inches (75mm) clear of concrete traffic barriers and all other falsework members are at least 12 inches (300 mm) clear. Do not remove barriers until approved.

   Use falsework columns that are steel with a minimum section modulus about each axis of 10 in^3 (150,000 mm^3) or sound timbers with a minimum section modulus about each axis of 250 in^3 (4,000,000mm^3).

   Mechanically connect the base of each column or tower frame supporting falsework over or immediately adjacent to an open public road to its supporting footing or provide other lateral restraint to withstand a force of not less than 2000 pounds (9kN) applied to the base of the column in any direction. Mechanically connect such columns or frames to the falsework cap or stringer to resist a horizontal force of not less than 1000 pounds (4.5kN) in any direction. Neglect the effects of frictional resistance.

   Mechanically connect all exterior falsework stringers and stringers adjacent to the end of discontinuous caps, the stringer or stringers over points of minimum vertical clearance and every fifth remaining stringer, to the falsework cap or framing. Provide mechanical connections capable of resisting a load in any direction, including uplift on the stringer, of not less than 500 pounds (2.2kN). Install connections before traffic is allowed to pass beneath the span.

   Use $^5/_8$ inch (16mm) diameter or larger bolts to connect timber members used to brace falsework bents located adjacent to roadways or railroads.

   Sheath falsework bents within 20 feet (6m) of the centerline of a railroad track solid in the area between 3 feet (1m) and 16 feet (5m) above the track on the side facing

the track. Construct sheathing of plywood not less than $^{5}/_{8}$ inch (16mm) thick or lumber not less than 1 inch (25mm) nominal thickness. Provide adequate bracing on such bents so that the bent resists the required assumed horizontal load or 5000 pounds (22kN), whichever is greater, without the aid of sheathing.

Provide at least the minimum required vertical and horizontal clearances through falsework for roadways, railroads, pedestrians, and boats.

9. *Falsework for Permanent Steel Structures.*

- *General.* Use falsework design loads consisting of the weight of structural steel, the load of supported erection equipment, and all other loads supported by the falsework. Do not apply loads to existing, new, or partially completed structures that exceed the load carrying capacity of any part of the structure according to the AASHTO Bridge Design Specifications.

  Build supporting falsework that will accommodate the proposed method of erection without overstressing the structural steel, as required, and will produce the required final structural geometry, intended continuity, and structural action.

- *Overhanging Forms for Bridge Deck Placement.* Brace or tie exterior girders, upon which overhanging bridge deck falsework brackets are hung, to the adjacent interior girders as necessary to prevent rotation of the exterior girders or overstressing the exterior girder web. Strut and tie exterior girders supporting overhanging deck falsework brackets to adjacent interior girders, or use needle beams clamped to the bottom flanges of the exterior girder and the adjacent interior girder. Do not weld to structural steel to attach forms or falsework.

  Design falsework and forms for concrete supported on steel structures so that loads are applied to girder webs within 6 inches (150mm) of a flange or stiffener. Distribute the loads in a manner that does not produce local distortion of the web. Space bracing and supports as needed, not exceeding 8 feet (2.5m).

10. *Falsework Construction.* Construct falsework to conform to the approved drawings.

Build camber into the falsework to compensate for falsework deflection and anticipated structure deflection. Camber shown on the plans or specified by the Engineer is for anticipated structure deflection only.

Attach tell-tales to the soffit of concrete forms in enough systematically placed locations to be able to determine from the ground the total settlement of the structure while concrete is placed.

Do not apply dead loads, other than forms and reinforcing steel, to any falsework until authorized.

Discontinue concrete placement and take corrective action, if unanticipated events occur, including settlements that cause a deviation of more than $^{3}/_{8}$ inch (10mm) from those shown on the falsework drawings. If satisfactory corrective action is not taken before initial set, remove all unacceptable concrete.

11. *Inspection and Certification.* When the falsework installation is complete and before concrete placement or removal begins, have the falsework inspected by a registered professional engineer proficient in structural design. Certify in writing that the installation conforms to

the contract, the approved falsework drawings (including approved changes), and acceptable engineering practices. Provide a copy of the certification before concrete placement.

(b) **Forms.**

1. *General.* Construct concrete forms mortar-tight, true to the dimensions, lines, and grades of the structure, and of sufficient strength to prevent appreciable deflection during placement of concrete. Unless otherwise specified, comply with the tolerance requirements (permissible variation from plan) of Table 502-4.

Table 502-4
Maximum Dimensional Tolerances for Cast-in-Place Formed Concrete[1]

Item	Tolerance, inch (mm)
Deviation from plan line[2]	±1 (25)
Cross-sectional dimensions of columns, piers and beams, slabs, and walls	+1 (25) -1/2 (12)
Bridge deck thickness	+1/2 (12) -1/4 (6)

1. Variations are to be compared with dimensions shown on the Plans or directed by the Engineer.

2. Tolerance measurement is perpendicular to the plan line or surface. This tolerance includes measurement of alignment, plumb, grade and level. Plumb (or batter) of retaining walls will be inspected both before and after backfilling.

Place all material required to be embedded in the concrete before concrete placement. Clean inside surfaces of forms of all dirt, mortar and foreign material. Remove all loose material before the completion of forming for the roadway deck slab of cast-in-place box girders or cells or voids of other members in which the forms are to either remain in place or be removed. Do not place concrete in forms until the forms have been inspected and approved.

2. *Removable Formwork.* Coat forms to be removed with form oil. Use commercial quality form oil or an equivalent coating that permits release of the forms and does not discolor the concrete.

Furnish and place form panels for exposed surfaces in uniform widths of not less than 3 feet (1m) and in uniform lengths of not less than 6 feet (2m), except where the width of the member formed is less than 3 feet (1m).

Arrange panels in symmetrical patterns conforming to the general lines of the structure. Place panels for vertical surfaces with the long dimension horizontal and with horizontal joints level and continuous. For walls with sloping footings which do not abut other walls, panels may be placed with the long dimension parallel to the footing.

Precisely align form panels on each side of the panel joint by means of supports or fasteners common to both panels. Provide 3/4 inch (20mm) triangular fillets at all sharp edges of the concrete.

Devices may be cast into the concrete for later use in supporting forms or for lifting precast members. Do not use driven devices for fastening forms or form supports to concrete. Use form ties consisting of form bolts, clamps, or other devices necessary to prevent spreading of the forms during concrete placement.

Do not use form ties consisting of twisted wire loops. Use form ties and anchors that can be removed without damaging the concrete surface. Construct metal ties or anchorages within the forms to permit their removal to a depth of at least 1 inch (25mm) from the face without damage to the concrete. Fill cavities with cement mortar and finish to a sound, smooth, uniform colored surface.

Make forms sufficiently rigid so that the formed concrete surface does not undulate more than $^{3}/_{8}$ inch (9mm), when checked with a 5-foot (1500mm) straightedge or template, or 1/360 of the center to center distance between studs, joists, form stiffeners, form fasteners, or wales. Interior surfaces of underground drainage structures are considered to be completely enclosed surfaces. Form all exposed surfaces for each element of a concrete structure with the same forming material or with material that produce similar surface textures, color, and appearance.

Support roadway slab forms of box girder type structures on wales or similar supports fastened, as nearly as possible, to the top of the web walls.

3. *Metal forms*. The specifications for forms relative to design, mortar tightness, filleted corners, beveled projections, bracing, alignment, removal, reuse, and oiling also apply to metal forms.

4. *Stay-in-place steel deck forms.*

4.1 *General*. Install forms according to approved fabrication and erection drawings. Do not rest form sheets directly on the top of stringer or floor beam flanges. Securely fasten sheets to form supports with a minimum bearing length of 1 inch at each end. Place form supports in direct contact with the stringer or floor beam flange. Make all attachments with bolts, clips or other approved methods. Do not weld form supports to stringer or floor beam flanges or reinforcing steel.

Clean, wire brush, and paint with two coats of zinc dust zinc-oxide primer, Federal Specification TT-P-641 type II, with no color added, any permanently exposed form metal where the galvanized coating has been damaged. Minor heat discoloration in areas of welds need not be touched up. Discard and replace forms damaged by bending or crimping.

Locate transverse construction joints in slabs at the bottom of a flute. Field drill $^{1}/_{4}$ inch (6mm) weep holes at not less than 12 inches (300mm) on center along the line of the joint. Lap adjacent forms and connect, by means other than welding, form sheets at a maximum of 18 inch (450mm) centers along the lap. In the lap, place on top the panel which will be loaded first during concrete placement.

Use epoxy coated reinforcing steel in bridge floors using stay-in-place forms. If epoxy coated reinforcing steel is not specified by the plans, provide epoxy coated bars at no additional cost. Do not use reinforcing steel, placed directly on the forms, as support chairs.

Provide means for inspection of the underside of forms after concrete placement. After a minimum of 48 hours of curing, the concrete may be tested for soundness and bonding of the forms by sounding with a hammer. Where directed, remove the forms in areas of doubtful soundness. Do not use a cutting torch to remove forms. Do not replace removed forms. Repair or replace concrete as required.

4.2 *Design Requirements.* Design stay-in-place steel deck forms to meet the following criteria.

- *Design Load.* Use a design load consisting of the weight of the forms, reinforcement and plastic concrete plus 50 lb/ft^2 (2400 Pa) for construction loads.
- *Allowable Bending Stress.* Limit the unit working stress in the steel form sheet to a maximum of 0.725 times the specified minimum yield strength of the material furnished, not exceeding 36 ksi (250 MPa).
- *Allowable Deflection.* Limit the deflection of form sheets to a maximum of 1/240 of the form span, not exceeding $^3/_4$ inch (20 mm). Use either the calculated design load or 120 lb/ft^2, whichever is higher, to calculate deflection.
- *Maximum Camber.* Limit form camber to not exceed the deflection under actual load. Do not use camber to compensate for deflection in excess of specified limits.
- *Design span length.* Consider the span length of the form sheets to be the clear distance between the flanges of the supporting beams minus 2 inches (50mm), measured parallel to the form flutes.
- *Design Properties.* Compute physical design properties under the requirements of the "Specification for the Design of Cold Formed Steel Structural Members," published by the American Iron and Steel Institute.
- *Weight Limitation.* Limit the combined weight of the forms and any additional concrete necessitated by the use of stay-in-place forms to a maximum of 10 lb/ft^2 (0.5 kN/m^2), in excess of the original plan weight of the bridge floor.
- *Deck Reinforcement.* Maintain the Plan dimensions of all deck reinforcement from the top surface of the concrete deck. Maintain all cover requirements shown on the Plans.
- *Flange Bracing.* Do not consider stay-in-place forms as lateral bracing for compression flanges of supporting structural members.

4.3 *Shop Drawings.* Prepare shop drawing for stay-in-place steel forms showing the following items as a minimum.

- The layout of the form sheets on the bridge floor identifying form sheets by piece marks.
- The steel grade, and dimensional and section properties for form sheets and supports.
- The type and spacing of chairs.
- Lap details and planned direction of concrete placement.
- Detail views of all connections.
- A complete bill of materials.
- Installation instructions.

(c) **Removal of Forms and Falsework.** Remove all forms except stay-in-place forms.

The removal of forms that do not support the dead load of concrete members, other than railings and barriers, shall not begin until the concrete has sufficient strength to resist damage to the surface. Protect exposed concrete surfaces from damage.

Unless otherwise specified, do not begin the removal of forms and falsework until the requirements specified in Table 502-5 for minimum time in the forms have been met. Do not release falsework for cast-in-place post-tensioned portions of structures until the prestressing steel has been tensioned.

Table 502-5
Form and Falsework Release Criteria

Forms and Falsework Supporting:	
Spans more than 14 feet (4.3m) (i.e., slab spans, pan girders, RCB decks, pier caps)	14 days
Spans of 14 feet (4.3m) or less (i.e., bridge decks on girders, RCB decks, diaphragms, pile bent pier caps)	10 days
Forms:	
Not supporting the dead weight of concrete (i.e., columns, walls, side forms for abutments & pier caps)	24 hours
For railings and barriers	12 hours

1. Continue curing under Section 509 after removing the forms for the structure. Refer to Section 509 for sequence of placement and application of load requirements.
2. Time periods assume concrete curing temperatures more than 50°F (10°C). Add one day for every day having concrete temperatures below 50°F (10°C).
3. Time periods for falsework release may be shortened at the discretion of the Engineer if the concrete has attained 80 percent of the specified strength.

Completely remove falsework material. Remove falsework piling at least 2 feet (0.6 m) below the surface of the original ground or original stream bed. Where falsework piling is driven within the limits of ditch or channel excavation, remove the piling to at least 2 feet (0.6m) below the bottom and side slopes of the excavated areas.

Leave the forms for footings constructed within a cofferdam or crib in place when their removal would endanger the safety of the cofferdam or crib, and where the forms will not be exposed to view in the finished structure. Remove all other forms whether above or below ground line or water level.

(d) **Temporary Retaining Structures.**

1. *General.* Perform excavation under Section 501 and the OSHA Standard outlined in 29CFR 1926, Subpart P. When a temporary retaining structure is required by the Plans, these Specifications, or the OSHA Standard, meet the following requirements.

   Sheet and brace vertical-sided excavations as necessary to retain the earth and water pressures and surcharges, and to protect adjacent property and facilities during construction of the permanent work. Use a registered geotechnical engineer to identify the soil type being excavated, if unknown. Use a registered structural engineer to design temporary retaining structures and prepare working drawings. Submit calculations and drawings for the temporary retaining structure before starting the work on the retaining structure.

2. *Cofferdams and Shoring.* Design and construct cofferdams and shoring for foundation construction to be as strong and watertight as necessary to properly perform the work. Size cofferdams to allow pumping outside the concrete forms and concrete placement in the dry.

   When water cannot be controlled so that the footing concrete can be placed in the dry, use a cofferdam with a Class A-concrete seal placed underwater below the elevation of the footing. Control the water level within the cofferdam during concrete seal placement to prevent water flow through the seal.

   Construct cofferdams so as to protect green concrete against damage from a sudden rising of the stream and to prevent damage from erosion. Do not leave bracing inside the permanent concrete structural members.

   Obtain approval to substitute round pier bases of equal stability for square or rectangular bases specified on the Plans. Submit plans of proposed round bases for approval before constructing.

   Unless otherwise specified, remove cofferdams and shoring with all sheeting and bracing after the completion of the footing, taking care to not damage the finished permanent work.

(e) **Temporary Water Control Systems.**

1. *General.* Temporary water control systems consist of dikes, bypass channels, flumes and other surface water diversion works, cutoff walls and pumping systems, including wellpoint and deep well systems, used to prevent water from entering excavations for structures.

2. *Working Drawings.* When required on the Plans, submit working drawings for temporary water control systems according to Subsection 105.02. Include details of the design and equipment, operating procedures to be employed, and the location of the point or points of discharge. Design and operate the system in compliance with all applicable water pollution control and environmental requirements.

3. *Operations.* Pump from the interior of any foundation excavation in such a manner as to preclude the possibility of the movement of water through any fresh concrete. Suspend pumping ground water from an excavation during concrete placement and for 12 hours (longer if directed) after concrete placement, unless using a sump separated from the concrete work by a watertight wall or other effective means. Before pumping to dewater a sealed cofferdam, allow the seal to set sufficiently to withstand the hydrostatic pressure.

Regulate pumping from wellpoints or deep wells to avoid damage by subsidence to adjacent property.

(f) **Detour Bridges.** Construct and maintain the detour bridge according to the contract documents or an approved alternate design.

For alternate detour bridge designs, use a registered professional engineer to design and draw the detour bridge. Submit signed and sealed working drawings and calculations for approval of the alternate design according to Subsection 105.02. The alternate design must be equivalent in all respects to the design and details shown on the Plans. Use the same roadway width and traffic rail specified on the Plans. In the submittal, show clearances, alignment, load capacity, pay item quantities, and other design parameters specified. Design according to AASHTO *Standard Specifications for Highway Bridges.* Use an HS20-44 live load, unless otherwise specified in the contract documents.

To utilize used beams, verify that the beams satisfy the minimum section modulus required by the approved design. Account for section loss due to corrosion, or bent, cracked, or damaged flanges or webs, and fatigue life. Replace unsatisfactory beams as directed at no additional cost to the Department.

Remove detour bridges as specified or directed. Beams shall become the property of the Contractor at the conclusion of the project unless otherwise specified. Painting of beams that are to become the Contractor's property shall not be required.

502.05. METHOD OF MEASUREMENT.

Forms, including stay-in-place forms, will not be measured for payment. Include the cost of forms in the unit price bid for the appropriate concrete pay items. When stay-in-place forms are used for bridge floors, concrete and reinforcing steel quantities will be computed based upon the conventionally formed design shown in the contract drawings.

Engineered falsework, not including engineering services, will be measured as a lump sum. *Falsework engineering services,* when required, to design, draw, inspect, and certify falsework will be measured as a lump sum.

Other falsework will not be measured for payment. Include the cost of this falsework in the unit price bid for the appropriate concrete pay items.

Temporary retaining structures and temporary water control systems will not be measured for payment. Include the cost of this work in the price bid for related excavation pay items.

Detour bridges, not including piling or drilled shafts, will be measured as a lump sum. Piling and drilled shafts will be measured as specified in the contract documents.

502.06. BASIS OF PAYMENT.

The accepted quantities, measured as specified in this Section, will be paid at the contract price per unit of measurement for the pay items listed below that are shown in the Plan bid schedule. Payment will be full compensation for the respective work prescribed in this Section.

(A) ENGINEERED FALSEWORK ..... .LUMP SUM
(B) FALSEWORK ENGINEERING SERVICES ..... LUMP SUM
(C) DETOUR BRIDGE ..... LUMP SUM